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MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY.

COMMUNICATED BY E. B. TITCHENER.

XI.—SOME QUESTIONS OF THE CUTANEOUS SENSIBILITY.

BY W. B. PILLSBURY, A. B.

INTRODUCTION.

This article gives the results of a series of experiments made during the academic year 1893-94, at the Cornell Psychological Laboratory. The method employed was the second of those used by E. H. Weber in his classic investigation of cutaneous space relations. A point on the skin was touched and the subject requested to indicate the point stimulated as accurately as possible. The average error of such attempts at localization afforded a relative measure of the space sensibility of the skin. Weber himself considered this average error an absolute measure of the local sensibility of the part of the skin worked upon. He says: "Bestimmt man mit einem Zirkel und Maasstabe wie weit der Beobachter von dem gesuchten Orte entfernt bleibt, wenn er demselben am nächsten zu sein glaubt, und nimmt aus vielen solchen Bestimmungen das Mittel, so wird man finden, dass es desto weiter von ihm entfernt bleibt je unvollkommener der Raumsinn in dem Theile der Haut ist an welchem der Versuch gemacht wird."¹

1. Czermak objected that this average error must be in every case too small, and therefore rejects the method entirely. He says:² "Bei dieser Bestimmung spielt der Zufall eine so bedeutende Rolle dass der Werth des ganzen Verfahrens zur Ermittlung der Feinheitgrade des Raumsinnes in Frage gestellt wird. * * * Hier hilft es auch

¹Ueber den Raumsinn, pp. 89-90. In the *Verhandlungen d. k. sächsischen Gesellschaft d. Wissens. in Leipzig. Math.-phys. Classe*, 1852.

²Physiologische Studien, 2te Folge, pp. 52-53.

nicht das Mittel aus vielen Beobachtungen zu ziehen, da die Bestimmungen in überwiegender Zahl zu klein sind, das Mittel daher auch zu klein ausfallen muss. Bei dem Verfahren mit dem Zirkel ist die Bestimmung durch zwei Grenzwerte, einen kleinsten und einen grössten beschränkt, während bei diesem Verfahren nur der eine und zwar der grösste Grenzwert nicht überschritten werden kann, indem es für dieses Verfahren gar keinen kleinsten Grenzwert gibt. Der kleinste Grenzwert ist hier $= 0$, wenn nämlich die suchende Sonde zufällig die zuerst berührte Hautstelle findet. * * * Aus dem gesagten ergibt sich nun von selbst dass das zweite Weber'sche Verfahren zur genaueren Bestimmung der Feinheit des Raumsinnes in der Haut gänzlich unbrauchbar sei.'

In his statement of the facts, Czermak is unquestionably correct. The average error will necessarily be smaller than the limen of twoness. But his conclusion that the method is for this reason useless is not so unexceptionable. For, although itself too small, the error must nevertheless bear a constant and mathematically determinable relation to the limen. It is plain that within the figure formed by the limen, one point would be hit upon as often as any other in an infinite number of experiments. Within the limen there is no diverting agency which would tend to favor one point rather than any other. All would be determined by the laws of chance. The case is not analogous to that of shots fired at a target, where there is a conscious endeavor to hit the centre. For the consciousness of the subject, the figure bounded by the limen is a mathematical point. Centre and circumference are one for him. Consequently, his attempt to touch the figure bounded by the limen has no effect in directing a point towards the centre rather than towards any other point within its area.—It might be supposed, on the other hand, that the periphery would be favored; approach being usually made from the outside. But the localization is frequently made from above, and at the first attempt. Even when a point outside the limen is first touched, and the correction made by moving along the surface, the exploring pencil generally moves around in all directions in the neighborhood of the point sought, and often finally stops only on the far side of it. This lack of directing agency is not only theoretically demonstrable, but is proved by an examination of our results.¹

If we should average the errors made on every radius of the

¹The absence of preference of the periphery in this context of *amount* of localization error does not, of course, conflict with the tendency to localize in a certain *direction*, noticed below.

figure formed by the limen, and plot on the radii the averages thus obtained, we should have a line bounding a figure similar to that bounded by the limen and dividing the area of the limen into equal parts. This line of average error would, *i. e.*, contain the same area within it as was contained between it and the limen. By the law of similar figures, the distance from the point touched to any point on the line of average error would be to the distance from the same point to the corresponding point on the limen as 1 to $\sqrt{2}$. From this it is evident that the mean error of localization can be used as a measure of discrimination for the comparison of different points of the skin ; and its reduction (multiplication by $\sqrt{2}$) will give a value comparable with the value of the limen as determined by other methods. This, then, is one of the points to which we desire to call attention in the present investigation.

2. Another of the principal objects of the investigation was the determination of the part played in localization by the visual image, which the reagent *Wn.*¹ had already found to be an important factor in all cutaneous space judgments. To obtain this a number of series were made with the subject localizing so far as possible in terms of tactual sensations alone, followed by a number of series in which as much prominence as possible was given to the visual image. In order still further to increase the prominence of the visual image, the person experimented upon, during series of a third type, kept the eyes open and fixed on the arm during the application of the pressure, and then closing the eyes localized as before.

3. A third problem was the testing of the results obtained with the photograph-method of Henri. In this the subject localized the point touched upon a photograph of the arm instead of upon the arm itself. Here again we find the visual image playing an important rôle, but under several new and complicating influences.

EXPERIMENTS.

Our investigation was restricted to an area of the volar side of each forearm, extending from the folds of the skin at the base of the palm to a point some nine centimeters up the arm towards the elbow. This area was subdivided into twelve by two longitudinal and three horizontal lines. Only one experiment was made on each of these parts during a single

¹*Ueber den Einfluss der Gesichtsassociationen auf die Raumwahrnehmungen der Haut. Phil. Stud. XI, 2.* As Miss Washburn's paper is logically prior to the present, the latter has been withheld from publication until the appearance of the *Studien*.

experimental series, as it was found that the after-effect of pressure exerted a disturbing influence upon judgment. It was often noticed during the first few days of experimentation, when this point had not been observed, that the after-effect of a preceding experiment was mistaken for the impression given to be localized. Even when this mistake was not made, the subject was conscious of a confusion due to the same cause.

During experimentation the reagent sat with eyes closed or open, as the method required, the arm resting comfortably on a table. The experimenter touched a point on the skin with a charcoal point; the reagent indicated the point touched with another and similar charcoal point. The error made in this localization was then measured with a compass and scale. Care was taken that the charcoal points should be of the same size—one millimeter in diameter. Record was made both of amount and direction of error. The directions were divided into eight groups, for convenience of record: right (R.), left (L.), peripheral or towards wrist (P.), central or towards elbow (C.), and the directions midway between these: *L. P.*, *R. P.*, *L. C.*, and *R. C.* The subjects were Miss Washburn (*Wn.*), Messrs. Knox (*K.*), Read (*R.*), Titchener (*T.*) and Watanabe (*We.*). With the exception of *R.*, all had had experience in experimental work, and all the rest except *K.* in experiments on this same portion of the arm.

All methods of collecting the results from a limited number of experiments are liable to objection. Two methods of massing the experiments from different positions are open to us. The results may be averaged, each result counting for one, without reference to the position of stimulation; or the average may be obtained for each position and then the average values of the various positions averaged. The first method may be very unfair to some particular position, since the errors are determined in their position by chance, and the sensibility of the skin is very different for different positions. There might, for instance, be a large proportion of all the errors towards the wrist (*P.*) made at some point of great sensibility. If averaged directly, the value for *P.* in the given case would be much too small. This objection would, of course, hold against any method of determination in which care was not taken that an equal number of experiments were made on each portion of the part of the skin which was being investigated. The other method allows the fewer experiments equal weight with the larger number, and in a very limited number of experiments may give rise to serious errors. These, however, are at most chance errors, and will

disappear with an increase in the number of observations. As the lesser of the two evils, we have chosen the latter method of 'massing.'

1. The results obtained from two reagents in one investigation of the *effect of visualization*, massed as explained above, are given in Table I.

TABLE I. *Unit = 1 mm.*

<i>Reagent T.</i>			<i>Reagent Wn.</i>		
Without Viz.	With Vis.	EyesOpen.	With'tVis.	With Vis.	EyesOpen.
7 Series. 168 Ex.	7 Ser. 168 Ex.	8 Ser. 192 Ex.	19 Ser. 456 Ex.	19 Ser. 456 Ex.	20 Ser. 480 Ex.
<i>P.</i> = 8.35	4.09	3.95	4.26	4.56	3.03
<i>C.</i> = 8.59	4.76	5.20	4.76	5.03	2.84
<i>R.</i> = 6.65	2.45	3.18	2.28	3.52	2.35
<i>L.</i> = 7.57	5.11	3.27	3.38	3.49	2.62
<i>R. P.</i> = 6.78	4.80	4.49	4.10	5.19	3.00
<i>L. P.</i> = 6.88	4.92	5.28	3.03	3.58	3.79
<i>R. C.</i> = 9.03	5.28	4.78	5.03	4.62	2.78
<i>L. C.</i> = 7.13	6.88	5.14	5.21	2.95	2.74
60.98	38.29	34.39	32.37	32.94	23.15

We give only the results from *T.* and *Wn.* All the others show the same tendencies as *Wn.* The sums of all the errors are given merely for convenience, this appearing the best means of showing at a glance the relations between the different series. Nothing is claimed for them as averages.

In the case of every reagent the experiments of the first seven or eight days were disregarded, so that practice may be considered constant throughout the entire table. The series of each day was not long enough to give rise to fatigue. The experiments seldom required more than half an hour a day.

The results show that none of the reagents, with the exception of *T.*, were able voluntarily to control *visualization*. All, during the experiments themselves, frequently said that they found it impossible to shut out the visual image, and

their results show no difference between the experiments performed with and without visualization. *T.*, however, found it possible to exclude the visual image to a large extent, was positive of the fact as indicated by introspection during the observations, and shows in his results a very marked difference between the two methods.

2. As regards the influence of *position*: we find the longitudinal divisions to be about on a par, so far as can be decided from the experiments performed. Right, left and centre of the wrist seem to show an equal error. In several cases there was an indication of a slight superiority on the outside of the arm, *i. e.*, the right side of the right arm and the left side of the left; but the results are not concordant enough to be decisive on this point.

The differences between the horizontal divisions are more striking, as will be seen by a glance at Table II. In this table the Roman figures designate the distance from the base of the palm at which the observations were made; I. beginning at a distance of approximately 9cm., and the others approaching the palm by stages of about 3cm. Absolute exactness of stimulus position is not claimed, but the variation did not exceed ± 2.5 mm.

The first quantity at the foot of the column gives the sum of the errors in the position. It affords a good indication of the gradual decrease of the error as the wrist is approached. The second figure shows the relation between the horizontal and the vertical errors. In this fraction the numerator represents the horizontal, the denominator the vertical errors.

There are several exceptions to the general rule of the increase of the ratio between horizontal and vertical errors as the wrist is approached, but such exceptions are not more numerous than would be expected with such a small number of results.

Only selected results are given, to avoid too great length. The series chosen were from the more experienced subjects, and are those which include the greatest number of experiments. Where other means of preference were lacking, results were chosen that fairly represented the whole number. There is only one exception to the general law of the relation between horizontal and vertical errors, and none to the tendency to decrease toward the wrist, in the series of results not given.¹

In this table we see a constant decrease in the size of the error as we go toward the wrist. The greatest difference is either between the series taken near the base of the hand, on

¹No. of series published = 6. No. of series not published = 3.

TABLE II. *Unit = 1 mm.*
Reagent T.

WITH VIS. 7 Series. 168 Experiments.				EYES OPEN. 8 Series. 192 Experiments.			
I.	II.	III.	IV.	I.	II.	III.	IV.
<i>P.</i> = 5.83	4.54	4.84	2.00	6.28	5.19	3.06	2.49
<i>C.</i> = 5.84	6.85	3.25	3.72	7.38	6.09	3.84	3.00
<i>R.</i> = 1.00	3.45	2.62	3.39	2.97	3.67	3.02	2.79
<i>L.</i> = 3.13	3.75	4.50	3.75	Lacking	1.95	3.00	3.30
<i>R.P.</i> = 4.00	4.00	6.50	5.15	5.32	3.75	Lacking	3.00
<i>R.C.</i> = 6.08	4.15	5.13	Lacking	7.00	3.75	4.00	5.25
<i>L.P.</i> = 4.50	5.63	5.00	"	8.63	5.17	3.22	5.13
<i>L.C.</i> = 10.25	6.17	7.38	3.50	3.00	5.63	4.10	4.00
41.03	38.54	39.22	29.02 ¹	46.37 ¹	35.20	27.70 ¹	28.96
Ratio: 0.3530	0.6321	0.8801	1.2518	0.4349	0.4982	0.8725	1.1109

Reagent R.

Reagent We.

EYES OPEN. 7 Series. 168 Experiments.				NORMAL. 13 Series. 312 Experiments.			
I.	II.	III.	IV.	I.	II.	III.	IV.
<i>P.</i> = 5.20	5.56	4.33	1.70	9.67	8.13	6.26	5.75
<i>C.</i> = 5.36	4.54	4.50	2.25	4.25	4.25	4.63	1.88
<i>R.</i> = 7.25	2.00	2.33	1.50	5.42	5.32	3.03	2.69
<i>L.</i> = 4.25	4.13	5.00	1.23	6.00	5.14	5.09	4.84
<i>R.P.</i> = 4.50	3.25	5.67	5.00	8.63	7.13	7.50	6.75
<i>R.C.</i> = 8.00	4.37	1.00	4.75	7.00	5.00	4.50	4.10
<i>L.P.</i> = 5.84	7.25	3.50	3.50	8.75	6.17	6.70	3.54
<i>L.C.</i> = 5.50	Lacking	4.50	3.45	7.15	7.09	4.00	4.80
45.90	35.55 ¹	30.83	25.38	56.81	48.23	41.71	34.40
Ratio: 1.0890	0.6069	0.8301	0.6963	0.8204	0.8449	0.7457	0.934

¹The directions lacking are supplied by the average value.

Reagent Wn.

WITHOUT VIS. (Theoretically.) 19 Series. 456 Experiments.				EYES OPEN. 20 Series. 480 Experiments.			
I.	II.	III.	IV.	I.	II.	III.	IV.
<i>P.</i> =5.17	3.89	3.89	3.47	4.32	3.68	2.95	1.72
<i>C.</i> =5.10	4.15	4.68	3.27	3.50	3.84	3.18	1.84
<i>R.</i> =2.50	1.12	4.64	2.83	3.89	1.38	2.00	1.96
<i>L.</i> =3.92	3.39	4.59	2.17	2.44	2.14	3.09	2.36
<i>R.P.</i> =3.09	5.03	3.38	3.34	4.00	2.75	1.24	2.07
<i>R.C.</i> =5.26	5.27	5.50	4.00	2.50	1.63	3.00	4.50
<i>L.P.</i> =3.43	4.60	4.04	2.94	4.50	4.34	2.23	2.03
<i>L.C.</i> =6.83	6.07	4.76	3.17	2.25	3.55	2.38	2.00
35.30	33.52	35.48	25.19	27.40	23.31	20.37	18.68
Ratio : 0.5278	0.5609	1.0770	0.7418	0.8095	0.4681	0.8303	1.2135

the folds of the skin at the joint, and the other three ; or between the two upper and the two lower sets of observations. This difference is due, at least in part, to individual variations in the distance from the hand to which the folds extend. Not only does the size of the error decrease as the folds of the wrist are approached, but the form of the figure constituted by the limen changes in a marked degree. On the parts of the arm nearer the elbow, the longer axis of the ellipse formed by the limen is vertical ; on the folds of the skin at the joint, the horizontal axis bears a much larger proportion to the vertical axis, and in some cases becomes the long axis of the figure.

This change of direction seems in some way connected with the direction of the prominent markings, cords or folds, on the surface of the skin. The greatest error is made in the direction of such markings. That is, the greatest error is longitudinal on the higher parts of the arm, while near the base of the palm, where the folds also enter as prominent visual landmarks, we find the horizontal errors increase and in some cases become predominant in the final result. Moreover, during an experiment the reagent was often con-

scious of localizing by means of the image of the cords or folds. In several cases where an unusually large error was made, he would remark that it was 'on the same cord,' without knowing that the error made was exceptional. In a few instances it was found that one cord was mistaken for another.

The most obvious explanation is to be given in terms of the effect of visualization. The 'local signs' of the skin seem to be translated by association into terms of the visual image, and the localization made by means of a second association with the local signs. The experiment seems to be a search for a sensation of the same local sign as the original sensation. In this search the observer is first, and, in a general way, assisted by the association formed with the visual image, and through this with the appropriate motor sensation. As the exploring point touches the skin the local signs call up the associated visual image in terms of which, principally, the direction of the error is noted and the necessary corrections made. When a local sign and its associated visual image coincide with the local sign and visual image originally given, and for which the observer is seeking, the localization is considered as complete. In most cases, however, the local sign is to a great extent lost sight of, and the comparison takes place almost wholly in terms of the visual image alone. In such cases one would expect the result found in the experiments, that similarity in visual form should be accepted as identity in position. The great aid rendered by the visual image was noticed and frequently remarked upon by the reagents. They declared that they saw the point touched upon a mental visual image and used this image as a chart in their localization.

Another possible hypothesis might ascribe to the form of the surface a power of affecting the character of local signs. This would necessarily be in terms of the effect of physical structure on the transmission of the mechanical stimulus from the point touched to the nearest end-organs of touch. But the effect on the nerve endings could only be to give a difference in intensity, not in quality, and it seems impossible to frame a schema in accordance with which such delicate distinctions could be made by an organ of such comparatively gross sensibility.

3. In Table III. we give the average error, corrected as explained at the beginning of this article, for the error due to chance, *i. e.*, the value of the localization *limen*. The values for the upper part of the arm and for the folds of the skin are given separately. During the first experiments, no record was kept of the part of the wrist on which the error was made. For these series the average for the whole area of

skin investigated is given (column 3). In making the correction, only 1.4 of the value of $\sqrt{2}$ is used, as giving a sufficiently accurate result.

Throughout the Table, the Roman figures, as before, show the distances above the wrist at which the series were taken. I. is nearest the elbow, (about 9 cm. above the base of the palm); the others are successively 3 cm. farther from it.

The relatively small value of the limen, as determined by this method, must be in part due to the fact that the exploring point is moving over the skin, in part to the better attention of the reagent assured by the movements he must make, and in part to the additional aid rendered by associated movement sensations.

The increase of the error during visualization in We.'s results was probably due to the disturbing effect of introspection, and the attempt at control. It is to be noticed that in his case it is a comparison of normal localization, without regard to the visual image, and attempted visualization. With the other reagents there is an effort to visualize or not to visualize in the two series.

TABLE III.

Unit = 1 mm.		Mas'd I-III.	IV.	Mas'd I-IV.
T.	Without Visualization.	—	—	10.67
	With Visualization. Eyes Open.	6.93 6.25	5.08 5.06	— —
R.	With Visualization. Eyes Open.	8.81 6.55	6.93 4.08	8.91 —
We.	Normal.	8.57	6.02	—
	With Visualization.	9.27	6.47	—
K.	Normal.	6.86	3.47	7.55
Wn.	Without Visualization.	6.09	4.41	—
	Eyes Open.	4.14	3.63	—
	With Visualization.	—	—	5.94

4. Another interesting feature of the investigation was the constancy of the tendencies controlling the *direction of the error*. There are, evidently, several factors at work in the determination, within the limen, of the direction which the error will take. Some of these the investigation afforded a means of analyzing out. The most noticeable tendency was a displacement towards the wrist. The number of errors in

this direction is greater on the outside of the arm than on the inside, greater on the left arm, where the localization was made with the right hand, than on the right arm. The results from two reagents, tabulated to show this tendency, are given in Table IV. Here again we give the results from the reagents from whom we have the greatest number of observations. The results from the three methods, with visualization, without visualization, and with eyes open, are massed for convenience. All separately show the same tendencies. In collecting the results, the errors in the oblique directions were halved and one-half added to each of the principal directions between which the error was situated. In the abbreviations at the top of the columns, the first letter designates the hand, left or right, on which the experiment was made; the second indicates the part (left, centre, right) of the arm stimulated. The per cents. at the bottom of the columns show the ratio of peripheral errors to all errors made in the vertical line.

TABLE IV. Unit = 1 mm.

Reagent Wn. 58 series; 1,392 experiments.

L. L.	L. C.	L. R.	R. L.	R. C.	R. R.
$P. = 127\frac{1}{2}$	$P. = 93\frac{1}{2}$	$P. = 67\frac{1}{2}$	$P. = 35$	$P. = 65\frac{1}{2}$	$P. = 87\frac{1}{2}$
$C. = 36$	$C. = 38\frac{1}{2}$	$C. = 65$	$C. = 87$	$C. = 63$	$C. = 66$
78%	71%	51%	28%	51%	57%

Reagent T. 20 series; 480 experiments.

L. L.	L. C.	L. R.	R. L.	R. C.	R. R.
$P. = 39\frac{1}{2}$	$P. = 48$	$P. = 26\frac{1}{2}$	$P. = 23\frac{1}{2}$	$P. = 22\frac{1}{2}$	$P. = 21\frac{1}{2}$
$C. = 22$	$C. = 14\frac{1}{2}$	$C. = 21$	$C. = 28$	$C. = 20$	$C. = 29$
64%	76%	56%	46%	53%	41%

One important factor in causing this displacement towards the wrist is probably the overestimation of movements due to flexion and underestimation of those due to extension, when the arm is much flexed. As the reagent ordinarily sits at

the table with one arm resting on it, the other arm is naturally flexed nearly to its limit in making the localization. This view is strongly supported by the experiments of Loeb.¹ In exhaustive experiments made on the estimation of distance by movements of the hand, Loeb finds that there is always an overestimation where the muscles that give the initial movement are already contracted, and an underestimation where they are extended; *i. e.*, movements in flexion, where the limb is much flexed, are overestimated, and underestimated where the limb is much extended; for movements in extension the reverse is true. In translation from visual space (in terms of eye movements) into motor space (with hand movement), there is the same underestimation of movements of extension, increased by overestimation of the space moved through by the eye. In both cases the problem seems to be the same as our own—to determine the errors which arise when translating from the visual space diagram into muscular movements. In the second case, the results were affected by the divergence of the physiological visual space in the remoter parts of the field of vision from the normal visual space, while in our experiments, the normal visual space (which also probably formed the measure in Loeb's first case) was called up directly by the tactual impressions. We must replace Loeb's explanation of the phenomenon, that the errors in estimation are due to the differences in the extent of movements for the same amount of innervation, by an explanation in terms of a subjective equality between distances in visual space and the amount of sensations from the moving member. It is not that equal innervation sensations correspond to equal lengths of movement, but that equal lengths of movement give greater amounts of motor sensations, and these are taken to mean greater distances in the visual space diagram.

Of remotely related literature there is a little. Münsterberg's² pleasure-pain experiments on flexion and extension were evidently performed with the arm more extended, and, hence, would have no weight as compared with this position of the arm. Krohn's³ method, if fully made use of, would give important evidence as to whether the error is due to the cutaneous sensibility or "muscle sense," but the results are recorded in such a schematic manner and the whole investigation is so uncritical and apparently so inaccurate that but

¹ *Untersuchungen über den Fühlraum der Hand.* Pflüger's Arch., XLI, pp. 107-127. *Untersuch. über d. Orientirung im Fühlraum d. Hand u. im Blickraum.* Ibid., XLVI, pp. 1-46.

² *Beiträge*, 4tes Heft, pp. 216 ff.

³ *Journal of Nervous and Mental Diseases*, March, 1893.

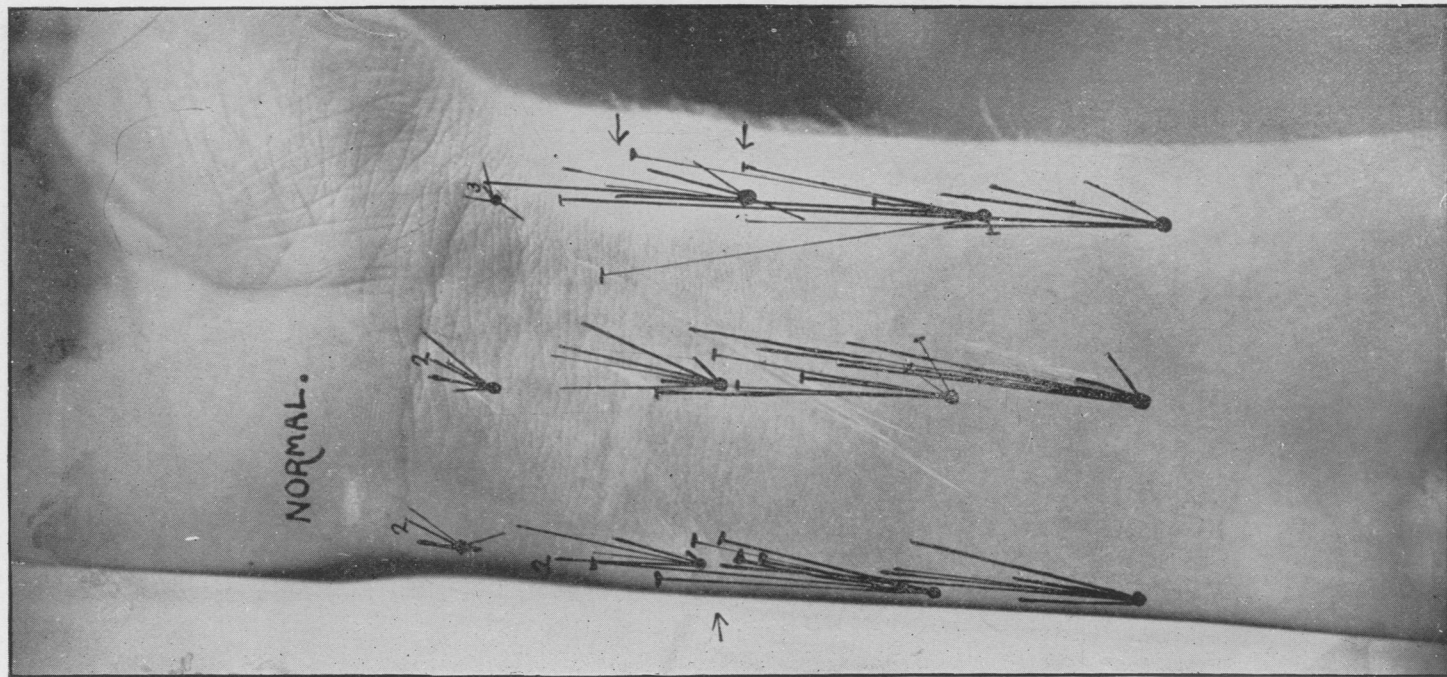
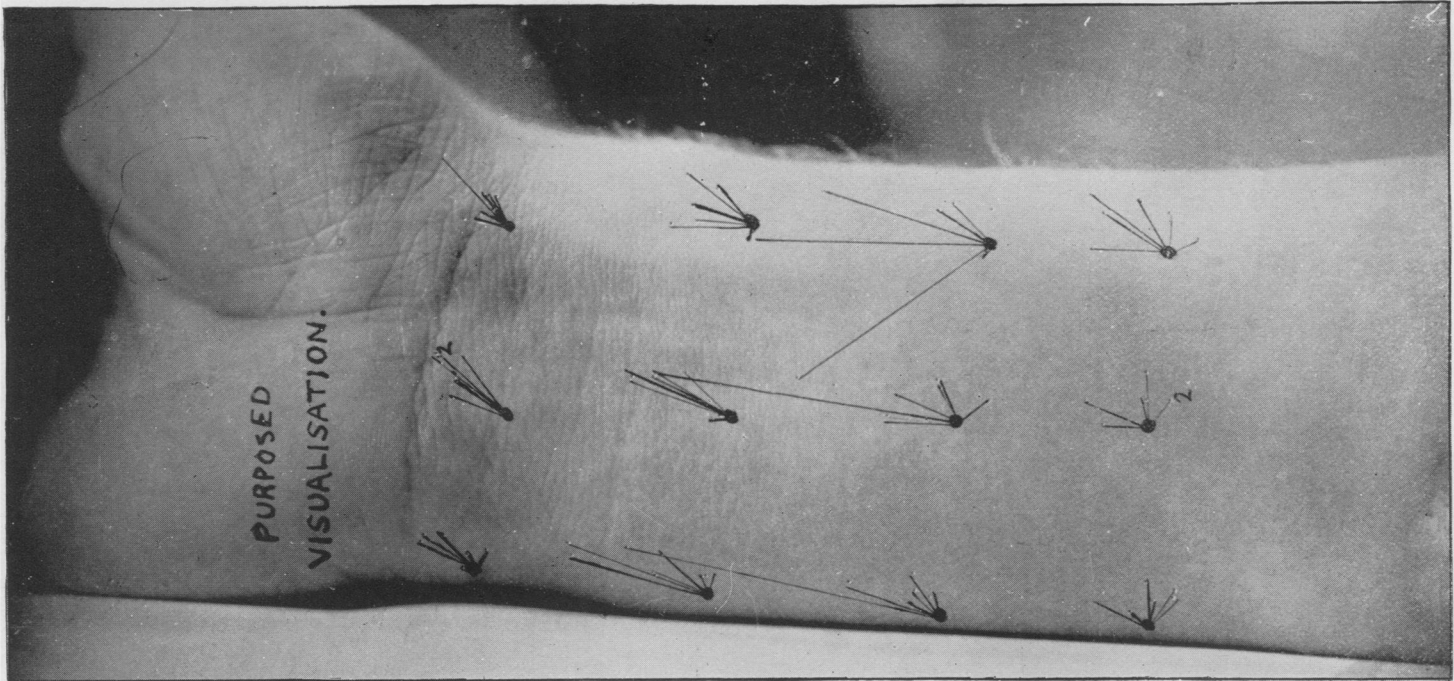
little can be obtained from it. Cattell and Fullerton¹ established the fact that small distances were overestimated and large underestimated. This probably is one of the more general laws under which these facts of displacement come. At extremes of flexion, further flexion gives more intense sensations (increases strain sensations in sinew and probably sensations of contraction in muscle also) than the same extent of movement in extension. Quantity of sensation is probably in part correlated in consciousness with extent of movement. We should then have a positive error in localization during extension, a negative error during flexion, and the point would be localized as we find it in our experiments, nearer the wrist than the point sought.

Further evidence for this hypothesis is given in our results by the increase of displacement as one proceeds from the inside of the arm (right side of left, left side of right), where the flexion of the arm is least, to the outside, where it is greatest. This factor, however, is to some slight extent crossed by the tendency to stop on the side of the given point from which it is approached. During the experiments on the left arm, the right hand usually rested near the wrist, or at a point more extended than the point given to be localized. During the experiments on the right arm, however, the left hand usually rested nearer the elbow than the point given. Consequently, in certain of the experiments we find this tendency added to the former on the left arm and subtracted from it on the right, where in some cases it completely nullifies the other.

There is also noticed, in general, some tendency away from the boundaries of the arm when the given point is on the side. During the first experiments, the reagent would occasionally miss the entire arm at the first attempt at localization. Probably fear of this error led him to localize further within than he otherwise would have done. The total results for all series show $196\frac{1}{2}$ errors away from the boundary and 143 towards it for *Wn.*, and $68\frac{1}{2}$ away and 58 towards for *T.* The other reagents show the same tendencies in about the same degree.

All the muscular tendencies noticed in this section are of influence only within the limen. They would, on *à priori* grounds, have no validity outside of the limen. Nor do they seem to determine the amount of the error within the limen. There is no relation noticeable between the tendency to localize in a given direction and an increase of the average error in that direction. An examination of the Tables will show

¹"On the Perception of Small Differences." *E. g.*, pp. 48, 49.



that the error in the direction *P.* is not proportionately larger than the others, in spite of the pronounced tendency to localize in that direction.

5. During the course of the investigation, the results of M. Henri's¹ experiments came to our notice. His reagents localized the impressions upon a photograph of the arm. The same method had already suggested itself to us, and was employed in some series of experiments. We give the results obtained from the reagent *T.* Two series were taken, one with visualization and the other without particular regard to the visual image.

During the experiments the reagent's arm was screened from his view. A point was touched on his arm, and the pressure continued while he localized it upon the photograph in front of him. The points experimented upon were approximately those used in the previous investigation. They were accurately marked and the same points used for each series. In order that the reagent should not be influenced by a knowledge of the schema, the photographs were used in such an order that the plan did not appear on any of them.

We give the results for the two series collected on single photographs. In the results it will be noticed that the error is in general much greater than in the former experiments, and the difference between the upper parts of the arm and the area marked by the folds of the wrist joint is much greater. This increase of the error is due, in all probability, to the lack of the correcting influence of the local signs present in the other method as the skin is touched in the search for the original stimulus. Here the first translation into visual space must suffice; there can be no further aid received from the new contacts. The folds of the skin at the joint, however, are prominent landmarks, to which the point can be accurately referred, and by whose aid it can be correctly localized. The cords are not so prominent in the photograph as on the skin itself, but in any case would only aid in fixing the point on its vertical line. The increased tendency to localize towards the wrist is in part due to an estimation of the distance in terms of the portion of the wrist usually exposed, without consideration of the increased surface offered by the turning back of the sleeve. Besides this, the tendencies noticed as effective in the other problem are at work with increased effect, since the restraining influence of the pure tactual limen of twoness is to a large extent lost.

¹*Récherches sur la localisation des sensations. Archives de physiologie*, No. 4, 1893, 619-627.

The increased power of localization, when the subject is visualizing, is very striking. Here the translation into visual terms before attempting to localize is more complete, and the subject is much better prepared to perform the localization with something like visual exactness.

On the whole, however, it seems that the errors avoided by the method are not so great as is the new one introduced. The problem changes its form to a certain extent, and becomes a matter of estimating the distance of a known point from different landmarks and then recording this estimation by a second estimation of distances in a slightly different field.

Postscript.—Since the above was written, Lewy's¹ article on memory has appeared. In this, use is made of the same method to test the memory of localization for both normal and pathological subjects, in the hope of discovering a method of diagnosing mental diseases. The results agree with our own so far as they cover the same ground. There is found the same marked displacement towards the wrist in all subjects. Lewy seems to incline towards an explanation in terms of the local signs, but does not attempt to give a full explanation. There is found the variation in the size of the error with the part of the arm experimented upon. This, however, is successfully avoided by using a very small portion of the arm. Fechner's method of mean error is used in interpreting the results without any compensation made for the error peculiar to this problem: that the average error is always too small. The various factors (visual, motor and tactual) that affect the memory do not seem to be well controlled in the experiments.

SUMMARY.

1. Weber's second method gives a valid measure of the limen after the proper correction has been applied to the average error of localization.

2. Every tactual impression is a compound. This can only be separated into its elements after much practice, and by persons of strong powers of attention and introspection.

3. The change of direction in the long axis of the limen, as one proceeds from upper arm to wrist, is probably due to the visual image connected with the pressure sensation proper.

4. The tendency to make an error towards the wrist is probably due to the overestimation of the extent of muscular movements of flexion as compared with movements of extension.

¹*Experimentelle Untersuchungen über das Gedächtniss. Zeitsch. f. Psych. u. Phys. d. Sinnesorg.*, VIII, pp. 231 ff.

5. Localization on a photograph, while giving some interesting results on other points, does not provide an accurate means of determining the limen of twoness.

X.—ON THE AFFECTIVE TONE OF SIMPLE SENSE-IMPRESSIONS.

BY D. R. MAJOR, B. S.

The aim of this study was largely methodological. We wished to test the validity of the serial method, already employed in æsthetics by Witmer,¹ and given by Külpe as one of the two principal methods of affective investigation.²

Our experiments were carried out in the months January to June, 1894. Just as we had prepared our material for publication, we received Vol. X., Pt. 4, of the *Philosophische Studien*, in which is contained J. Cohn's paper: *Experimentelle Untersuchungen über die Gefühlsbetonung der Farben, Helligkeiten, und ihrer Combinationen*. It seemed better to defer publication till we had compared the two sets of results. In what follows, therefore, constant reference will be made to Cohn's article.

Methodological.—Külpe writes of the serial method as follows: "Sie geht von der Thatsache aus, dass, wenn auch absolut die Gefühlswirkung eines Reizes unter verschiedenen Umständen sehr verschieden ausfällt, immerhin die einzelnen Reize das Gefühl in constanter Form *relativ* bestimmen oder beeinflussen können. Wenn ich z. B. in der Stimmung bin alle Farben gleichgiltig zu finden, so werde ich dennoch unter einer Anzahl mir vorgelegter Farbentöne Unterschiede ihrer Wirkung auf mein Gefühlsleben anzugeben im Stande sein Der Vorzug oder die Zurücksetzung, die den Werthen innerhalb einer solchen Reihe zu Theil werden, geben uns dann einen Aufschluss über die Abhängigkeit des Gefühls von den Reizen Eine strengere Ausbildung der Methode hat noch nicht stattgefunden Bei [ihr] ist offenbar die Abhängigkeit der Gefühle von den Reizen im allgemeinen nur durch eine Curve darstellbar, deren Verlauf die subjectiven Aenderungen zur Anschauung bringt, die einer bestimmten Aenderungsform der Reize entsprechen. Die einzelnen Werthe dieser Curve haben keine absolute Bedeutung, sondern sind lediglich abgestuft zu denken vom relativ Unangenehmsten bis zum relativ Angenehmsten Wir können uns die Gefühlsänderung selbst als einen rein

¹*Phil. Stud.*, IX., pp. 209 ff.

²*Grundriss*, p. 239.